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# **11T Magnet Development Effort with CERN**

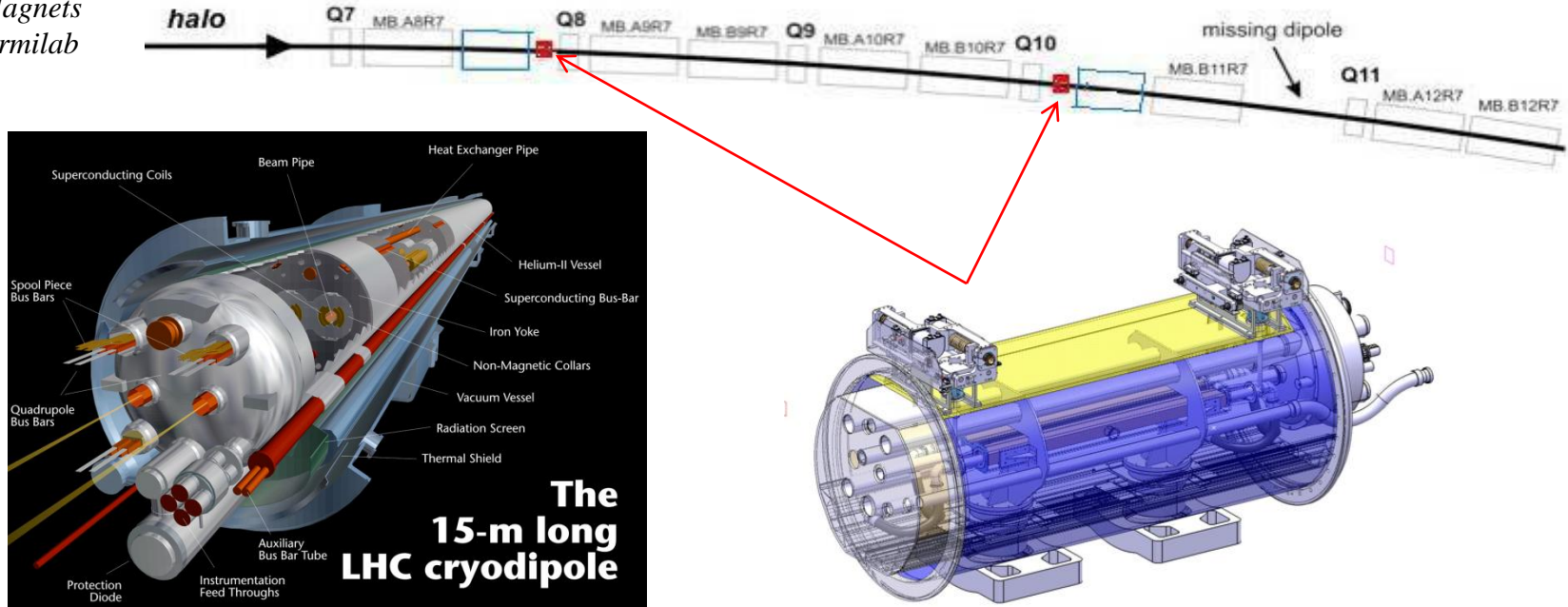
**Alexander Zlobin**

***Technical Division  
Fermilab***



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## Motivation

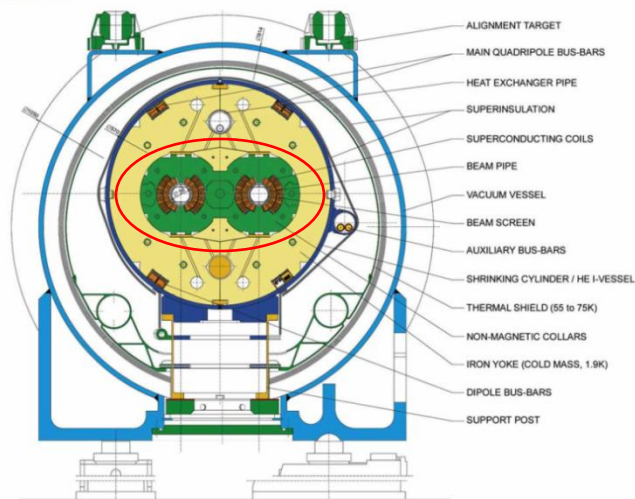


- ❖ LHC collimation system upgrade (2012-2016).
- ❖ **Phase II goal: intercepting off-momentum protons from single-diffractive scattering on cold collimators in the DS sections downstream of the collimation areas.**
- ❖ **11 T 11-m long double-aperture dipoles compatible with the LHC lattice and major systems provide the required space for cold collimators.**



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#### LHC DIPOLE : STANDARD CROSS-SECTION



- Same nominal current -11850 A
- Same cold mass OD - 570 mm
- Same distance between apertures -197 mm
- Nominal field – 11+ T
- 20% operational margin at 1.9 K
- $B_{\max}=13.2$  T

### ❖ Independent studies at CERN and Fermilab

- The nominal field of 11+ T at 11.85 kA with 20% at 1.9 K is possible with Nb<sub>3</sub>Sn coil
- the magnetic length varies between 10.7 and 10.5 m, thus resulting in dipoles 3.6 to 3.8 m shorter than the standard LHC dipole

### ❖ Nb<sub>3</sub>Sn magnet technology: available at Fermilab



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## **Challenges and Approaches**

### **❖ First 2-in-1 Nb<sub>3</sub>Sn magnet =>**

- **Common yoke, separate collared coils**

### **❖ Orbit sagitta => larger aperture**

- **56 mm => 60 mm**

### **❖ Long length ~11 m =>**

- **2 cold masses each 5.5-m long**

### **❖ Field quality =>**

- **small filaments ( $D_{\text{eff}} \sim 30 \mu\text{m}$ ) + passive correction to reduce persistent current effect**
- **SS core to minimize eddy current effect**
- **collar/yoke interface and holes to reduce iron saturation effect**

### **❖ Larger Lorentz forces**

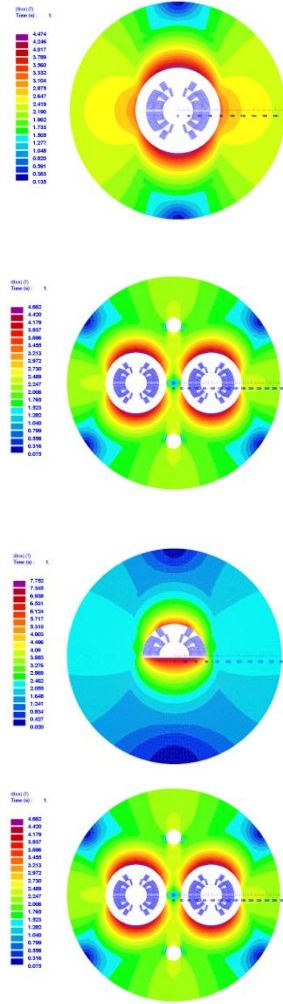


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## Activities and Deliverables

- ❖ FY11-12: Development and test of 60-mm single-aperture 2-m long 11 T DS dipole demonstration model
- ❖ FY12: Fabrication and test of two 2-m long collared coils for the first 2-in-1 DS dipole model
  - 2-in-1 cold mass assembly and test at CERN
- ❖ FY13: Fabrication and test of the first 5.5-m long dipole coils for DS dipole prototype
- ❖ FY13-14: Fabrication of 5.5-m long collared coil for the first 2-in-1 prototype
  - Long prototype assembly and test at CERN

Collaboration with CERN, **technology transfer.**





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## **Outcome**

- ❖ **In case of a successful demonstration and selection of these magnets for the LHC phase II collimation system upgrade, planned in 2016, a joint FNAL-CERN project to fabricate five (or more) 11 T 11-m long dipoles will be proposed for FY14-16**
  - **the first use of Nb<sub>3</sub>Sn magnet technology in real accelerator**
- ❖ **These magnets can be also used in the future to provide space in the LHC lattice for different insertion devices (dynamic collimators, correctors, instrumentation, etc.).**



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## **Program Approval**



**Fermilab**

Fermi National Accelerator Laboratory  
Technical Division  
Headquarters  
P.O. Box 500      Mail Stop 316  
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Phone: (630)840-4641

September 2<sup>nd</sup>, 2010

To:            Stuart Henderson, Associate Director for Accelerator  
From:        Giorgio Apollinari, Technical Division Head  
Subject:      Proposal for Development of 11 Tesla LHC Dipoles

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### **White Paper on**

### **CERN/FNAL Collaboration for the Development and Construction of Nb3Sn Dipoles for the LHC upgrades**

**G. Apollinari, A. Zlobin, Technical Division, Fermilab**

#### **1 Nb3Sn Accelerator Magnets Development**

Nb3Sn has been recognized as a viable superconductor for the construction of accelerator magnets since its discovery. In the last decade, the DOE has supported, through its OHEP branch, several R&D efforts aimed at the development of high-performance Nb3Sn strand advanced high-field accelerator magnets, in particular focusing on the quadrupoles to be used at the Large Hadron Collider (LHC) for luminosity increase toward the end of the present decade (2020). This latter effort, called LARP (LHC Accelerator Research Program) has involved the US national labs (LBNL, BNL, SLAC and Fermilab) and has recently successfully achieved the goal of building a ~4 m long 90-mm aperture Nb3Sn quadrupole reaching the field goal of 200





## **CERN Support**

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**Subject:** Letter of Support for Magnet Development Program

**Date:** Fri, 21 Jan 2011 14:12:56 +0000

**From:** Steve Myers <[Steve.Myers@cern.ch](mailto:Steve.Myers@cern.ch)>

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Dear Mike,  
Please find attached the  
will send a signed version  
Regards Steve

-----  
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In order to avoid the large over-heads associated with the removal and reinstallation of such a large number of superconducting magnets, CERN has recently considered the replacement of the existing LHC dipoles in question by shorter, higher field ones. The magnet groups from FNAL and CERN are already working together on a project called "11T-11m LHC dipole". This project is based on the advanced Nb<sup>3</sup>Sn technology program of DOE-LARP. In particular the FNAL team has a well-recognized technical expertise for dipole magnets to be operated at around 10-11 T and 50 mm aperture.

This letter strongly supports this program as a key component in the future upgrade of the LHC.

Presently, the total number of 11T-11m LHC dipoles needed is 8; i.e. 2 per side of each of the interaction points 3 and 4. A new scheme is presently being studied which could reduce the number of dipoles to 4, however, the feasibility has not yet been proven.

It is well known that the development of technically complicated components such as SC magnets requires a long lead time (from conception to actual hardware installation in the tunnel). **Consequently we strongly support the present program for the construction of a single bore, 1 m long model, which could demonstrate by 2011 the feasibility of such a magnet. We consider this program to be a significant contribution to the LHC and its upgrade, and we hope that DOE endorses the FNAL proposal of collaboration with CERN on such topic.**

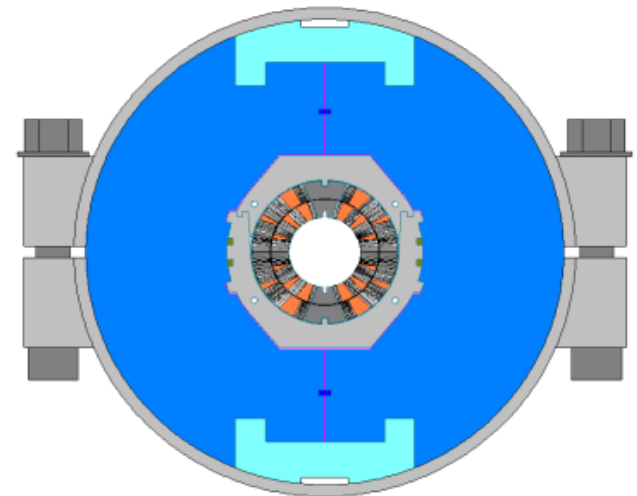
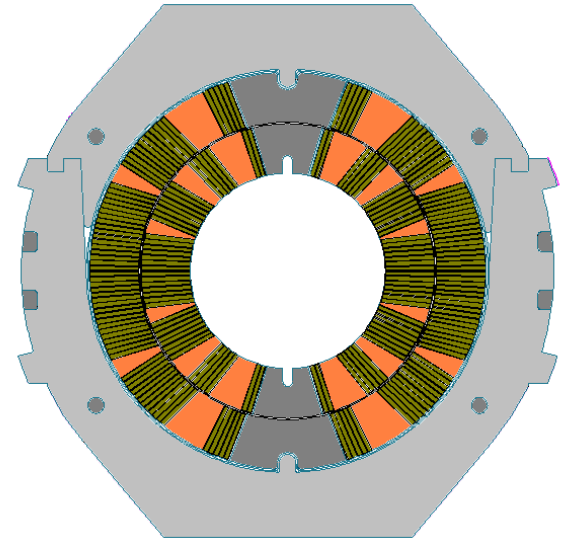




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## *Design and Parameters*

- ❖ **Strand: 0.7 mm RRP-108/127**
- ❖ **Cable: 40-strand 14.7x1.2 mm<sup>2</sup>**
- ❖ **Coil: 2-layer 7-block (CERN)**
- ❖ **Coil aperture: 60-mm**
- ❖ **Collar: stainless steel 20-mm**
- ❖ **Yoke: OD=400-mm, 2-piece**
- ❖ **Skin: 12-mm stainless steel**
- ❖ **Cold mass length 1.97 m**
- ❖  **$B_{nom}=11.31T$  @  $I_{nom}=11.85kA$**
- ❖  **$B_{max}=13.74T$  @  $I_{max}=14.39kA$**
- ❖ **Margin:  $B_{max}/B_{nom}=1.215$**





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# Specifications

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Number: **1107424 v.1**  
 EDMS Id: **1107424 v.1**  
**Under Approval**

Parameter and performance  
specification for the 11 T Dipole  
demonstrator model magnet  
[Mikko Karppinen, A.V. Zlobin](#)

**RESTRICTED**

Specification - Engineering Technical  
2010-12-14

**Summary** | Sub-Documents | Approval & Comments | Used in | Access Rights | Versions & other info

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**Description, External Reference and Keywords**

**Description** LHC collimation upgrade foresees two additional collimators installed near Q8 and Q10 quadrupoles in the dispersion suppressors of points 2 and 7. To obtain the necessary longitudinal space of 3 to 4.5 m for the collimators, a solution based on a 11 T dipole as replacement of the 8.4 T LHC main dipoles is being considered. CERN and FNAL have started a joint development program to demonstrate the feasibility of Nb3Sn technology for this purpose. The goal of the first phase is the design and construction of a 2-m long single aperture demonstrator magnet with a nominal field of 11 T at 11.85 kA current with 20% margin. This document defines the main magnetic and mechanical design and performance parameters for this demonstrator model magnet.

**External Reference**

**Keywords** Collimation upgrade, high field magnet, Nb3Sn dipole

❖ Specs in CERN EDMS

❖ Evaluate test results

**TE**  
TE-MSC

15 December 2010  
[mikko.karppinen@cern.ch](mailto:mikko.karppinen@cern.ch)

Group code: TE/MSC  
 EDMS no: 1107424

**Design and Parameter specification**

**11 T Nb<sub>3</sub>SN DIPOLE DEMONSTRATOR  
MODEL MAGNET**

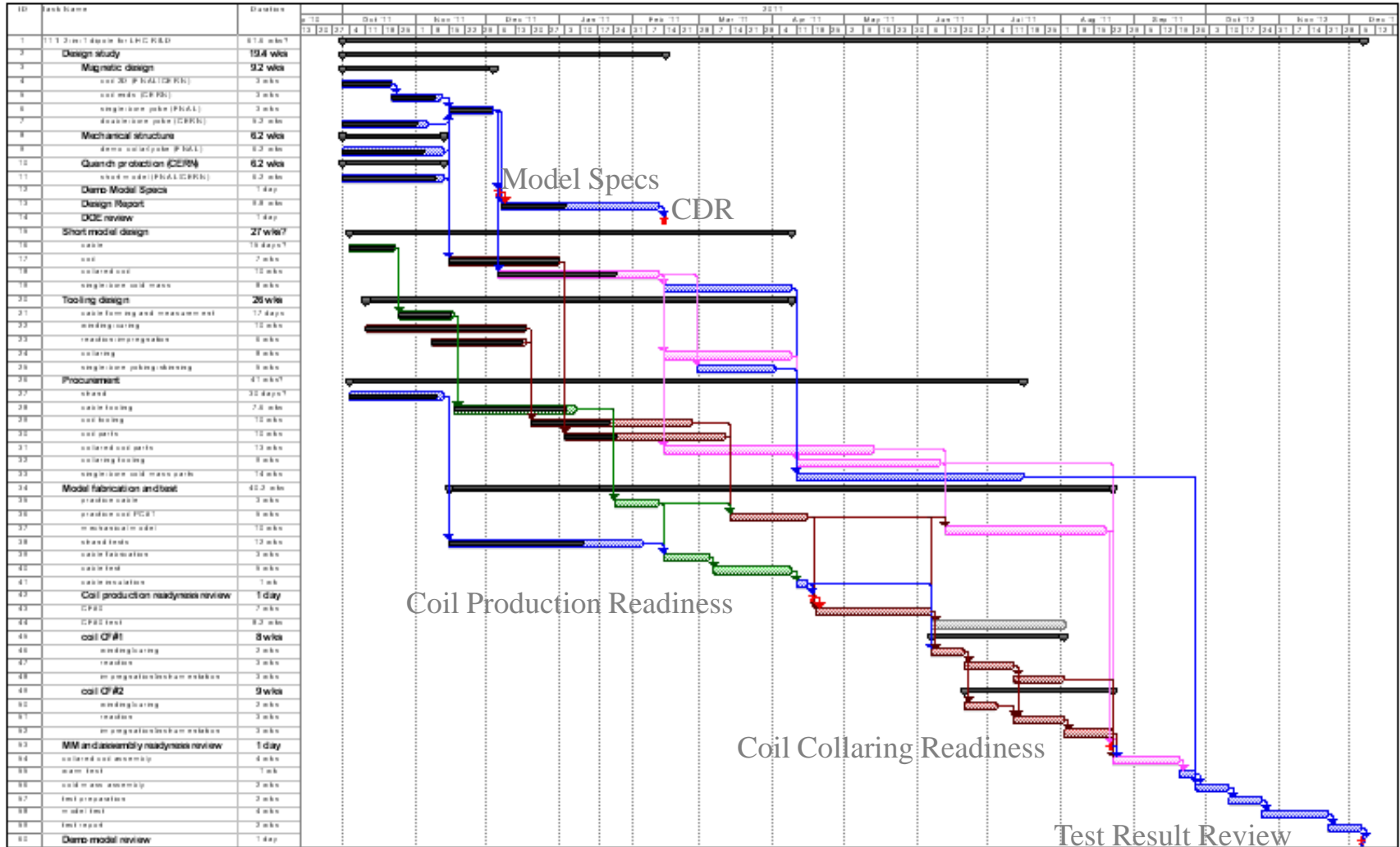
**Abstract**  
 LHC collimation upgrade foresees two additional collimators installed near Q8 and Q10 quadrupoles in the dispersion suppressors of points 2 and 7. To obtain the necessary longitudinal space of 3 to 4.5 m for the collimators, a solution based on a 11 T dipole as replacement of the 8.4 T LHC main dipoles is being considered. CERN and FNAL have started a joint development program to demonstrate the feasibility of Nb<sub>3</sub>Sn technology for this purpose. The goal of the first phase is the design and construction of a 2-m long single aperture demonstrator magnet with a nominal field of 11 T at 11.85 kA current with 20% margin. This document defines the main magnetic and mechanical design and performance parameters for this demonstrator model magnet.

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# Schedule & Milestones



❖ Good progress in October-January



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## *Is success possible?*

- ❖ **Specific features of this program, besides technical challenges, are its limited development time and resources**
- ❖ **The success is possible**
  - **high skill of Fermilab's magnet group**
  - **previous successful experience with the 10-12 T Nb<sub>3</sub>Sn dipoles and quadrupoles**
  - **available infrastructure and tooling**
  - **established productive collaboration with CERN**